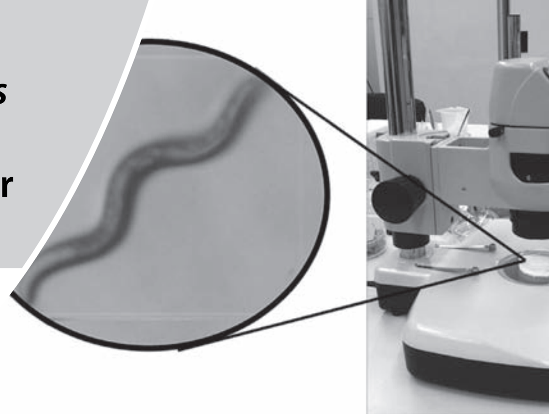
INQUIRY & INVESTIGATION

# Exploring *Caenorhabditis elegans* Behavior: An Inquiry-Based Laboratory Module for Middle or High School Students



NABT BioClub RECOMMENDATION

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**Abstract**

*The use of primary scientific inquiry and experimentation to develop students' understanding of methodologies used by scientists and the nature of science is a key component of the Next-Generation Science Standards (NGSS). Introduction to inquiry-based experimentation also has been shown to improve students' attitudes and interest in science. However, implementing scientific inquiry activities that include experimental design and data analysis in a classroom of middle or high school students can be daunting for teachers with limited experimental experience. Here, we present a four- to five-day, inquiry-based laboratory activity designed to teach students about the scientific process and excite them about scientific discovery while providing opportunities for interactions of both teachers and students with scientists in the field. Within this laboratory module, students make observations and develop their own research questions, then design, execute, analyze, and present the results of their hypothesis-driven experiments investigating the behavior of* Caenorhabditis elegans*, a relatively inexpensive and tractable model organism. Our experience running this module in a middle school biology classroom suggests students enjoyed the opportunity to investigate their own research questions, and post-course surveys indicated that students' fear of biology decreased and their interest in biology-related careers increased following participation in the module.*

**Key Words:** *Inquiry; lab; K-12; neurobiology; behavior;* C. elegans.

## ○ Introduction

Recent research has demonstrated that inquiry-based K-12 science instruction promotes conceptual understanding and improves student attitudes toward science and scientists (Houseal et al., 2014; Minner et al., 2010). Specifically, one study found that students taught using inquiry-based methods reached significantly higher levels of understanding across several tested learning goals and retained this knowledge over time (Wilson et al., 2010). Current NGSS science standards support this learning approach because they emphasize experimentation, as well as data analysis (NGSS Lead States, 2013). Unfortunately, a major barrier to the implementation of inquiry-based methodologies by K-12 classroom teachers is the fact that teachers often are not fully equipped to teach the scientific content or to employ inquiry-based practices (Buczynski & Hansen, 2010; Houseal et al., 2014; Jeanpierre et al., 2005). However, recent work suggests that fostering interactions between scientists and grade school science teachers promotes teacher confidence and content knowledge (Brown et al., 2014; Buczynski & Hansen, 2010; Tanner et al., 2003).

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To overcome barriers to inquiry adoption for teachers and to promote hypothesis-driven inquiry and scientific career exploration in school classrooms, we created a four-day inquiry-based module, in which students work with scientists for two days to learn about the model roundworm *Caenorhabditis elegans*, which they then use to experimentally investigate their own basic science questions. Based on our pilot of this module, we suggest extending this to a five-day module, using the extra day to perform additional experiments (Table 1). The module culminates with the students' creation of posters describing their experimental questions and results; these posters are presented in a poster session ideally held at a local university, where students have the opportunity to explore science research areas and careers while meeting with science majors and faculty. This type of student-driven experimentation meets several NGSS standards, including practice standards such as experimentation and data analysis, as well as crosscutting concepts such as the recognition that the technology and methods available limit scientific knowledge (NGSS Lead States, 2013). Moreover, the "meet the scientist" approach to science education has been shown to improve

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**Table 1. *C. elegans* inquiry-based laboratory module outline.** The laboratory module is split into four (or, preferably, five) days. The daily activities and estimated time allotments are included for each day, as is the experimental phase or topic being covered.

| | Experimental Phase | Activity (Student Handout Page Numbers) | Time |
|---|---|---|---|
| Day 1 | Introduce *C. elegans* model | Use microscopes to visualize wild type and mutant *C. elegans* under dissecting microscopes. Draw images of worms and record observations about their movement in lab notebook. (pages 1–2) | 30 minutes |
| | Describe types of neurons and how they control muscle movement | Listen to interactive PowerPoint presentation based on the information in handout about basic nervous system structure and function and how neurons control muscle movement in *C. elegans*. Brainstorm ideas about the types of things to which *C. elegans* might move in response. (pages 3–4) | 15 minutes |
| | Develop question, hypothesis and experimental design | Separate into groups of 3–4. Decide on an interesting scientific question and develop an hypothesis. Begin to design the experiment and determine supplies needed. Get experiments approved by instructor for scientific soundness and feasibility. (That is, the instructor can obtain all supplies necessary and experiment will fit into the time frame available in class.) (pages 4–6) | 30 minutes |
| Day 2 (and 3) | Experiment | Separate into groups and do experiments. Record results and observations on handout. Use extra time to begin to analyze data, draw conclusions, and prepare group presentation. (pages 5–7) | 75 minutes |
| Day 3 (or 4) | Poster preparation | Separate into groups and prepare posters in scientific format: Introduction, Methods, Results, and Conclusions/ Future Directions. | 75 minutes |
| Day 4 (or 5) | Present results;<br>Field trip to university (optional) | Present research results in a poster in scientific conference style.<br>(optional) Visit a local university and interact with faculty and students to learn about different types of scientific research, as well as different scientific career opportunities and degrees. | 45 minutes (poster presentations);<br>5 hours or as desired (optional field trip) |



interest and retention in STEM fields, particularly among underrepresented students (Laursen et al., 2007; Wilson et al., 2010), and exposes students to scientists from many backgrounds, another NGSS crosscutting concept. This module can be used to delve deeper into classroom units on genetics, physiology, or the basics of the scientific method. The overarching goal of this laboratory module is to engage and excite middle or high school students about biology and science.

## ○ Materials

- Dissecting microscopes with lighting from below and zoom to a minimum of 30x
- *C. elegans* strains: These can be obtained (free/subsidized for teachers upon request) from *Caenorhabditis* Genetics Center (CGC) (https://cgc.umn.edu). Wildtype (N2), *rol-6* (CB187), *bli-1* (CB769), *dpy-10* (CB128)
- 60 mm NGM agar plates of worms per strain (1 plate/group on day 1; 1–2 plates of the strains requested by each group for day 2 and/or 3). To prepare these plates, transfer ~4 worms of the strain to a clean plate seeded with OP50 bacteria four days prior to days 1 and 2/3.
- NGM plates (60 mm) seeded with OP50 *E. coli* or untreated NGM plates. Pre-poured NGM agar plates are available online (http://store.p212121.com/worm-plates-1-sleeve/ or other sources), or they can be prepared if you have access to sterilized solutions (Supplemental Material 1). OP50 *E. coli* can be obtained for free from the CGC website above. LB media and plates can be purchased or prepared (Supplemental Material 1).

Though in our trial of this module the teachers and scientists prepared the worms and the OP50, under the proper supervision, students could assist with this work. Having students record the preparation steps and methods can help them learn the careful preparation required to ensure the validity of their experiment, troubleshoot errors in preparation if necessary, and provide them more complete insight into the process of "real science."

Both *C. elegans* and OP50 are Biosafety level 1, meaning they do not cause disease in healthy individuals and thus require only standard microbiological safety protocols. Thus, students should be briefed on proper lab safety, including hand-washing, not drinking or eating in the lab, and proper clean-up of workspaces at the conclusion of the lab period.

### Worm Transferring Supplies

- Metal spatulas
- Alcohol, Bunsen burner, or other flame source
- 70% ethanol

*C. elegans* can be transferred onto another plate using a metal spatula to cut a small square of the NGM agar (with the worms on it) and putting it face down on another NGM plate; instructors would do this for younger students.

### Materials for Student Experiments (e.g., ice, sugar, tooth picks, etc.)

Although it is ideal to give students as much freedom to design experiments as possible, it is more practical to give students a set list of items they can use that are readily available around the lab and classroom and let students design experiments using these items.

Experiments will vary based on the class; however, the following are a few ways to assess worm movement. Worm migration to a chemical/food can be tested; to do this, put worms in the middle of the plate, the food/chemical on one side, and a control (such as water or the liquid in which the chemical or food was dissolved) on the other side. Use a toothpick to dab small amount of liquid onto the plate where desired. After a set time period (10–20 minutes, typically), count how many worms move to the chemical compared to the number that move toward the control. Alternatively, if the goal is to test the effect of a liquid on worm movement specifically, rather than testing their ability to sense a chemical, then the liquid must be placed on top of the worms, and the number of worm body bends counted over a given period of time (a minute or two). The liquid will cause the worms to move a lot initially, so an acclimation period of a minute should be used before counting begins, and a control of water or other dissolving agent should be used. The liquids can be added to the worms on the plate using a micropipettor or dropper under the dissecting microscope.

- Worksheet (Supplemental Material 2) or Simplified Worksheet (Supplemental Material 3)
- PowerPoint (Supplemental Material 4) or Simplified PowerPoint (Supplemental Material 5)
- Tri-fold posterboard
- Glue, scissors, markers to make posters
- Pre-/Post-module attitude questionnaire (optional, Supplemental Material 6) (Russell & Hollander, 1975)

## ○ Unit Overview

This module is designed for 36 students in a sixth grade biology class and three instructors, including one classroom teacher and two Ph.D. scientists; however, the module could easily be scaled for different class sizes and can be implemented by a teacher and one helper. Throughout the module, students work in groups of three or four. The first two to three days of the module are held in the school science classroom and require a 60–75 minute class period. The fourth day, students make posters during the class period. Day five can be run as a full day (5 hour) field trip to a local university during which students present their experimental findings and interact with college students and faculty; however, if the field trip is omitted, presentations can be done in the classroom during a 45–60 minute period.

### Day 1

On the initial day, students are introduced to *C. elegans*, observe these organisms, and learn the scientific method as they progress through activities on a lab worksheet (Supplemental Material 2). This worksheet, along with a short PowerPoint (Supplemental Material 4) projecting images from the worksheet, is used to introduce students to *C. elegans* as a model organism and later to explain how neurons regulate muscles to control organismal movement in response to stimuli.

Following their initial introduction to the worms, students observe wildtype worms of various larval and adult stages under the dissecting microscope. To do this, the room is split into 12 sections, each with a microscope and one plate of each type of worms. The student groups are each assigned one station. Students utilize the microscope to look at the plate of worms and record observations about the worms' appearance and movement. Students are then introduced to various mutant worms: *rol-6* (move in circles rather than in S shapes), *bli-1* (have large blisters), and *dpy-10* (are short and stumpy). Students make observations about wildtype and mutant worms, hypothesizing how the mutations may affect the worms' lives and movement. Based on the concept that neurons regulate movement in response to stimuli, and with guidance from the instructors, students work within their groups to generate a scientific question related to understanding how *C. elegans* move and respond to their environments. An hypothesis and a prediction based on that hypothesis are generated by the students to experimentally answer their question. Each question and hypothesis are reviewed by the instructors to determine the feasibility of the project. Students then design experiments to test their hypotheses using appropriate controls. Experiments are reviewed by the instructors, who also obtain a list of worm strains and materials needed for the next lab period.

### Day 2 (and Day 3, for 5-day module)

On day two, student groups work independently throughout the class period to perform their experiments, record results, and discuss their findings. To teach proper scientific methodology, instructors emphasize reproducibility and data collection as they monitor the groups' progress. Data are recorded in lab notebooks for later analysis. In a 60- to 75-minute period, groups should have sufficient time to redo experiments if modifications are needed, and to repeat their experiments in triplicate; however, if time permits, it is recommended that students be given two days for experimentation, to maximize opportunities for students to fully optimize their experiments and to allow sufficient samples sizes for quantitative analysis.

### Day 3 (or Day 4, for 5-day module)

On the third/fourth day, under the guidance of the classroom instructor, students design scientific posters describing their experiment and presenting their findings. Students assemble into their groups and are instructed to divide their poster board into at least 4 sections: (1) an Introduction to explain their initial question, hypothesis, and prediction related to the worms' movement; (2) a Methods section explaining what they did and how they did it; (3) a Results section depicting any data in a graph, table, or photographs, and explaining any qualitative assessments they made; and (4) a Conclusions/Future Directions section describing what they learned, aspects they would modify if they repeated their experiment, and ideas for future related experiments.

### Day 4 (or Day 5, for 5-day module)

On the final day of the module, student groups present their experimental results in a scientific poster presentation. Half of the students stand by and present their posters during the first 20–30 minutes of the period, while the other students listen to their presentations, then groups switch positions for the remaining 20–30 minutes. To encourage students to talk to each other about the research, students are required to take notes on 4 or 5 different group posters.

### Optional

The poster presentations are easily done in the classroom; however, to expose students to a wider variety of scientific research and to provide additional opportunities for them to interact with college science students and faculty, we took our group of middle school students to a local university, where they had the opportunity to explore college life and careers in science. We arranged for the students to observe a cell culture lab, a lab working on developmental biology in *Drosophila*, and a *C. elegans* neurobiology lab, as well as to visit and learn about the science occurring in the campus greenhouse and prairie. University faculty members and students helped by discussing various types of science and scientific career paths as students explored these facilities.

## ○ From the Classroom

We ran this module with a class of 34 sixth grade students in an honors biology class at Westlane Middle School in Indianapolis, IN. The class was composed of 18 girls (53%) and 16 boys (47%). Twenty-one (62%) of the students were white, and 13 (38%) were from underrepresented minority groups, either African-American or Hispanic. Although each class and classroom experience will be different, below are two examples of experiments designed by the middle school students who participated in our laboratory module:

*Question*: Does sugar make *C. elegans* hyper?

*Hypothesis/Prediction*: If sugar makes *C. elegans* hyper, then when you feed *C. elegans* sugar, the worms will move more.

*Experiment*: Put sugar in water and place on a plate of *C. elegans*. As a control, place water with no sugar on *C. elegans*. Monitor movement by counting worm body bends during a 30-second interval.

*Instructor Notes*: Numerous groups were interested in assessing *C. elegans* behavior in response to chemical stimuli: sugar water, caffeine, energy drinks, etc. Though an interesting concept, it proved challenging to assess since *C. elegans* move (swim) nearly continuously in liquids like these, and changes in their rapid movement are difficult to monitor. Additionally, it was critical to make sure students had thought of an appropriate control condition. For example, students concluded the energy drink stimulated the worms in comparison to untreated animals; however, the students needed to assess control worms in a liquid such as water rather than worms crawling on the plate. To their credit, the students often realized such flaws during their experiments.

*Question*: How do *C. elegans* respond to a block in their path?

*Hypothesis/Prediction*: If *C. elegans* can crawl around an obstacle, then when the path to food is blocked, *C. elegans* will go around the block to their food.

*Experiment*: Place Legos between *C. elegans* and their food and observe movement.

*Instructor Notes*: This ended up being an interesting experiment; the worms crawled over and under obstacles. This experiment needed a bit more time to set up, as the worms we used were not starved or hungry (in fact, many were sitting on their food to start), making them less inclined to move. This experiment may have worked better with worms that were washed or not on a plate with food to begin with; however, due to time constraints, this experiment could not be replicated. Again, the students generated many of these ideas for future directions, once they identified the limitations of the experiment. This said, the experiment was very successful, with students observing worms moving over and under the Legos. If we had an additional day for experimentation, as we suggest here, this experiment likely would have generated even more interesting data.

Overall, most student experiments were at least partially successful; however, as with all real science, most of the initial student experiments had flaws. This is expected, particularly given the limited time students had to design and implement their experiments, and the need to trouble-shoot and optimize experimental protocols should be pointed out to students as a critical part of the scientific process. Students should be prompted to assess their findings and the scientific merit of them, including whether the results really showed what they had hoped to determine and whether other controls or modifications to the methods were needed. In our experience, most students were able to identify ways in which they could improve their experimental design in the future, even if many did not obtain fully interpretable results from this single day of experimentation. The reliability of the results would likely increase substantially if given an additional day in which to modify and run their experiments (5-day protocol).

Regardless of their experimental outcome, groups were instructed to discuss a future direction they could explore experimentally to further address their experimental question and hypothesis. If students did not have enough time to complete the experiment or if the method they had chosen did not work, students were encouraged to describe the problem, the result they obtained, and then to determine an alternative approach that could be used. For example, a group of students hypothesized that Neosporin could heal the blisters on the *bli-1* strain of worms and predicted this treatment would help *bli-1* worms move. The group used toothpicks to spread globs of Neosporin on the worms. However, they observed that no matter how small of a glob they used, it was significantly larger then these microscopic worms, impeding worm movement. To address this problem, the group suggested developing a microscopic needle to apply the Neosporin or watering down the Neosporin so it did not impede worm movement. In this way, students were allowed to delve into their questions and hypotheses further, and develop real-world solutions to problems they encountered while performing their experiments.

We assessed the effects of the module on student attitudes toward scientific career opportunities and opinions of science and scientists by using a pre- and post-module questionnaire (Supplemental Material 6) (Russell & Hollander, 1975). This assessment, which was voluntary and anonymous, was performed in class prior to the first day of the module and after the final day. Students created unique code names so we could pair their pre- and post-module assessments. Likely based on our limited class size and the sample pool, responses to only two questions reached or approached significance (Table 2).

First, we found that after the module students had reduced negative feelings toward biology, with a borderline significant reduction in students identifying with the statement "I don't like biology, and it scares me to have to take it." (Q2, $p = 0.058$). Furthermore, we found a slightly larger pre- to post-module decrease in negative feelings associated with biology when only assessing students who initially were unlikely to pursue science as a career option (Q2, Pre-Module 2.0 ± 0.62, Post-Module 1.70 ± 0.78, $p = 0.058$ for students who ranked their likelihood of pursuing a scientific career as 3 or less on Q16, "I can see myself becoming a biologist in the future."). This suggests that a hands-on, student-driven approach to discovering the scientific method may reduce anxiety associated with biology.

Second, students were significantly more likely to see themselves as obtaining a scientific career in biology following our module (Q16, $p = 0.03$). Whether this increase was caused by the inquiry-based laboratory or the exploration of scientific careers at Butler University is not clear. A larger study assessing students from diverse classes would be necessary to fully understand the implications of this inquiry-based laboratory. Furthermore, the class we assessed was an honors class, with students who already had high opinions of science; assessing responses to these questions after implementing this module in different classrooms may result in even larger differences.

Finally, to determine students' opinions of the module, we asked students to write on post-it notes one positive aspect of the module, one negative aspect of the module, one thing they found particularly interesting about the module, and one suggestion to improve the module in the future (Table 3). Numerous students stated that designing their own experiment was their favorite part,

**Table 2. Student pre- and post-module responses to science attitude questions.** Students were administered a questionnaire prior to the start of the module and after the final day of the module to assess their attitudes about science. Students were asked to choose a number between 1and 5 to reflect their level of agreement with the statements list, with 1 being strongly disagree, 3 undecided, and 5 strongly agree. The numbers listed are the average of the class ± the standard deviation. For **statements in bold type**, the pre- and post-answers were statistically different based on a standard paired Student's *t*-test, with $p \leq .05$.

| Question # | Pre-Module Responses | Post-Module Response |
|---|---|---|
| 1. Biology is very interesting to me. | 3.90 ± 0.70 | 3.87 ± 0.87 |
| **2. I don't like biology, and it scares me to have to take it.** | **1.90 ± 0.64** | **1.65 ± 0.74** |
| 3. I am always under a terrible strain in a biology class. | 1.90 ± 0.90 | 1.93 ± 0.91 |
| 4. Biology is fascinating and fun. | 3.90 ± 0.82 | 4.00 ± 0.90 |
| 5. Biology makes me feel secure, and at the same time is stimulating. | 3.40 ± 0.66 | 3.58 ± 0.87 |
| 6. Biology makes me feel uncomfortable, restless, irritable, and impatient. | 2.00 ± 0.90 | 2.00 ± 1.15 |
| 7. In general, I have a good feeling toward biology. | 4.03 ± 0.69 | 4.06 ± 0.98 |
| 8. When I hear the word "biology," I have a feeling of dislike. | 1.90 ± 0.70 | 1.80 ± 0.90 |
| 9. I approach biology with a feeling of hesitation. | 2.20 ± 0.70 | 2.20 ± 1.04 |
| 10. I really like biology. | 3.90 ± 0.66 | 3.90 ± 0.87 |
| 11. I have always enjoyed studying biology in school. | 3.65 ± 0.86 | 3.60 ± 1.05 |
| 12. It makes me nervous to even think about doing a biology experiment. | 1.90 ± 0.69 | 2.00 ± 0.86 |
| 13. I feel at ease in biology and like it very much. | 3.80 ± 0.87 | 3.60 ± 1.07 |
| 14. I feel a definite positive reaction to biology; it's enjoyable. | 3.70 ± 0.85 | 4.00 ± 0.98 |
| 15. I enjoy talking about biology with my family and/or friends. | 3.30 ± 1.10 | 3.00 ± 1.25 |
| **16. I can see myself becoming a biologist in the future.** | **2.48 ± 1.04** | **2.80 ± 1.06** |
| 17. It is important for everyone (even non-scientists) to understand the scientific process. | 4.10 ± 0.82 | 4.10 ± 0.77 |

**Table 3. Student informal feedback on the module.** Students were asked to anonymously (using post-it notes on a large paper taped to the wall) give feedback on their favorite aspect of the inquiry module, something they found interesting or learned from the module, something they did not like (a minus from the module), and to give a suggestion on how they would improve the module. Below is a sample of the most common student responses for each category.

| | Student responses |
|---|---|
| Favorite | "Being able to do more interesting experiments" |
| | "My favorite thing of everything we did was coming up with an experiment because I love testing things." |
| | "I liked that we got to design our own experiments and not have it be already planned and strictly enforced because then I just feel like we're doing arts and crafts." |
| Interesting | "The worms were interesting in how they are like us." |
| | "I thought the glowing worms were interesting because there has to be a certain light." At Butler University |
| Minus | "My minus was having such little time to conduct our experiments and work on our posters." [*Note: There were several complaints like this, so we may need to allow more time in classes in between module days for this.*] |
| Suggestions | "Make more time to learn about *C. elegans* because that is what our experiment is based on." |
| | "Longer experimental times" [*Note: Numerous students made this suggestion.*] |
| | "Let us use worms more." |



and all enjoyed the interactions with students and scientists on the college campus. The students' most common suggestion was to extend the time allotted for experimentation. Our own observations suggested the students would have benefitted from an additional day in which they could have adjusted and repeated their experiments; thus we recommend extending experimental time if possible to allow students more opportunities to trouble-shoot and thus, hopefully, gather more interpretable data. Nevertheless, even in the single class period, students learned valuable lessons about the precision needed to perform meaningful scientific experiments and were excited by the process of participating in the scientific process.

## ○ Conclusions

Inquiry-based laboratory modules introduce students to the practices scientists use in real-world experiments, engaging students in investigations, data analysis, and scientific communication. In this inquiry-based module, students are exposed to numerous learning outcomes expressed in the NGSS Understandings about the Nature of Science, including both crosscutting concepts and practices associated with Understanding the Nature of Science (NGSS Lead States, 2013). Specifically, students design and conduct their own experiments related to understanding *C. elegans* movement, analyze the data from their experiments, and draw conclusions based on those data. Students also present their data using graphs, tables, and photographs in a scientific poster session, which is key for establishing scientific communication skills and in line with new standards of science literacy (NGA Center for Best Practices, 2010).Such involvement of students in authentic research improves student engagement and learning about the scientific process and increases retention in science and motivation for graduate studies (Eagan et al., 2013; Hunter et al., 2007; Lopatto, 2007; Russell et al., 2007; Weaver et al., 2008). The added benefit of interactions between classroom science teachers and scientists can increase teacher knowledge and confidence (Brown et al., 2014; Buczynski & Hansen, 2010; Tanner et al., 2003).

Together, the results from the pre-/post-module questionnaire and qualitative student responses imply that our inquiry-based laboratory increased appreciation and enjoyment of biology in middle school biology students from diverse backgrounds, even in students not intending to pursue biology as a career. Adding additional experimentation time would likely improve this module; however, this may be difficult given time constraints of class periods and the need to cover other content. This module was designed and implemented by two Ph.D. scientists with extensive training in *C. elegans* neurobiology in conjunction with a sixth grade science teacher who has an elementary education degree with a middle school science endorsement; however, the module could be simplified if it seems daunting to middle or elementary school teachers who are attempting to implement this module on their own. We have included a simplified worksheet and presentation that can be used (Supplemental Materials 3 and 5) to avoid some of the detailed neurobiological terminology in our original materials. Additionally, a wide array of videos, protocols, and *C. elegans*–related resources geared toward K-12 teachers are available online, and we would be happy to consult with any teachers interested implementing this module. We also envision this module could be modified for use with high school students, who would be expected to design more sophisticated experiments with detailed quantitative analyses, such as using the chemotaxis assay described in the module handouts and PowerPoint files (Supplemental Materials 2–5), rather than observational experiments. In conjunction with these quantitative experiments, high school students can be expected to generate graphs depicting their data, including calculating standard deviations for each dataset, and to use basic statistical analyses, such as Student's *t*-test, to compare the means of experimental and control groups. Ideally, this module can be widely implemented to introduce middle or high school students, particularly those from underrepresented minorities, to scientific inquiry and scientific careers.

### Approvals

Pre- and post-module student questionnaires were reviewed and registered as exempt by the Butler University Institutional Review Board (October 5, 2015).

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